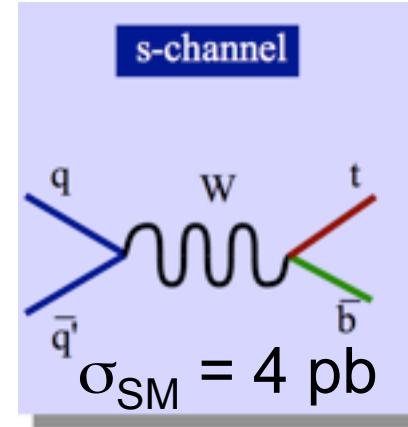
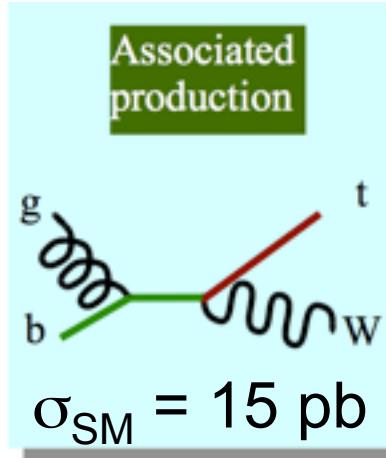
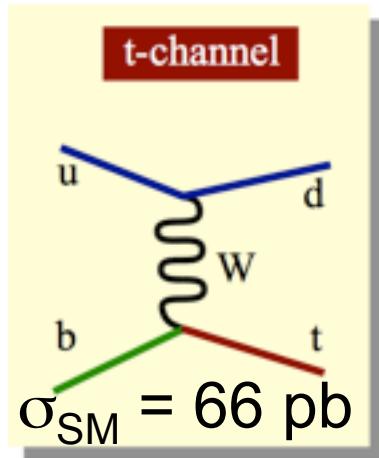


Searches for Single Top-Quark Production with the ATLAS Detector in pp Collisions at $\sqrt{s} = 7 \text{ TeV}$

Reinhard Schwienhorst
Michigan State University
For the ATLAS collaboration

Physics at LHC 2011
Perugia

Single top quark production



- Key to understanding electroweak interactions of top
- Sensitive probe to many new physics models
- Small signal, large backgrounds
 - Requires detailed understanding of entire detector
- 2010 data analysis: t-channel and Wt search
- 2011 data analysis: t-channel observation

[ATLAS-CONF-2011-027](#)

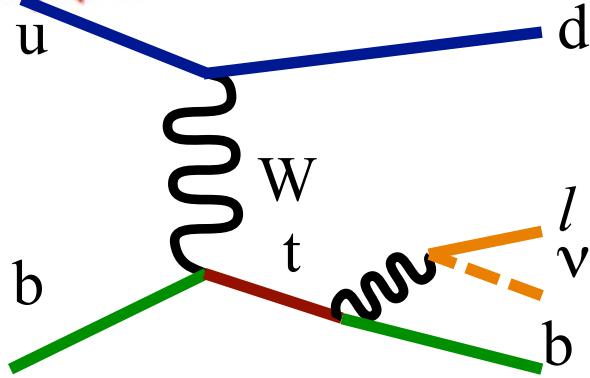
[ATLAS-CONF-2011-088](#)



σ_{SM} computed with MC@NLO, mtop=172.5GeV, CTEQ6.6 PDFs



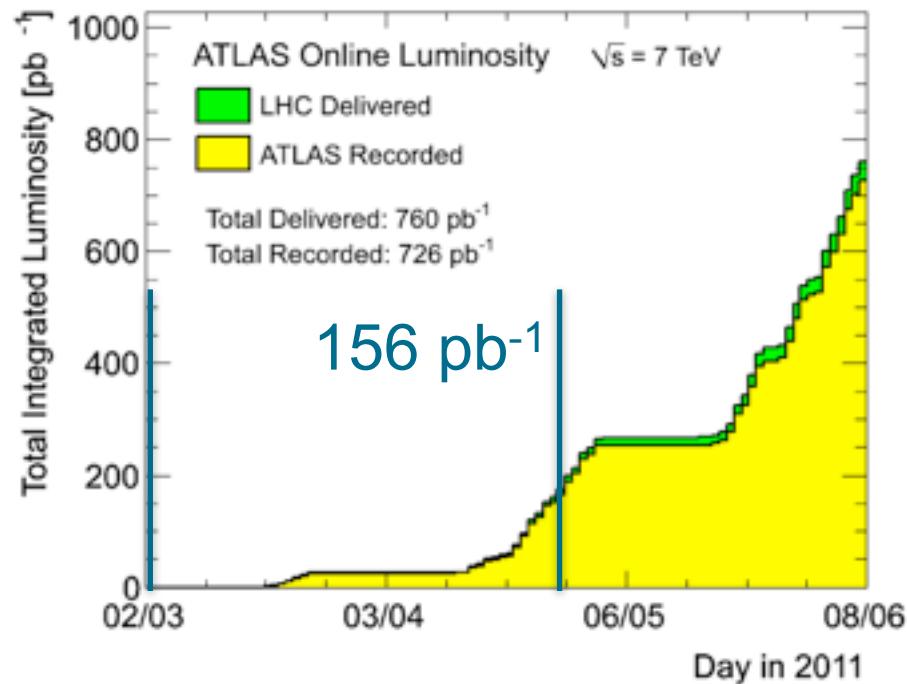
Measurement of t-channel production



- 156 pb⁻¹ of 2011 ATLAS data
- Lepton+jets final state

Event selection:

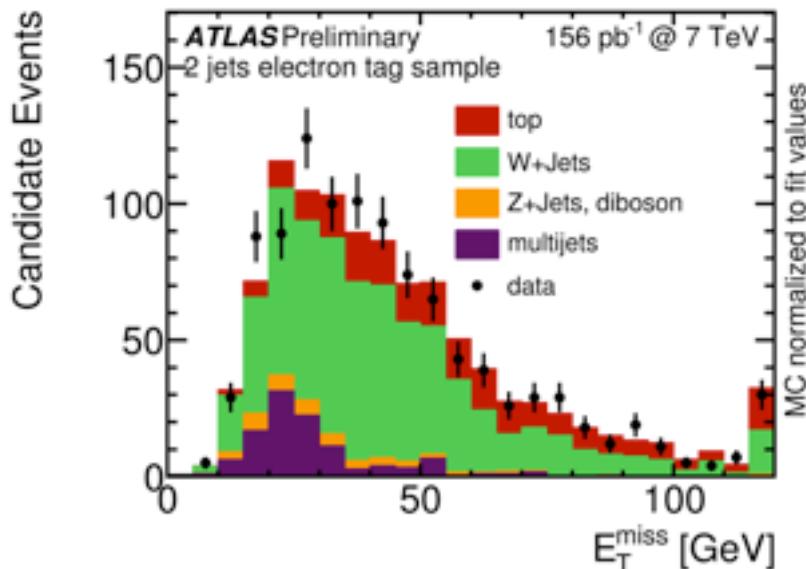
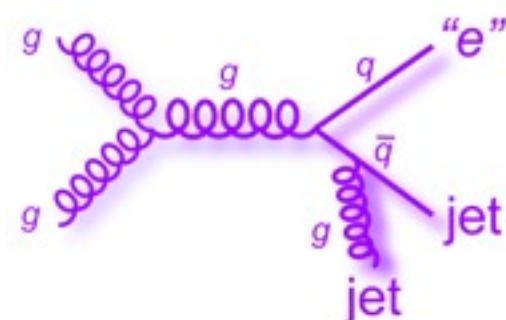
- Single lepton triggers
- 1 electron or muon
 $E_T(p_T) > 25 \text{ GeV}$
- $E_T^{\text{Miss}} > 25 \text{ GeV}$
- = 2 jets ($p_T > 25 \text{ GeV}$), = 1 b-tag
- $M_T > 60 \text{ GeV} - E_T^{\text{miss}}$ (multijet veto)



Background modeling

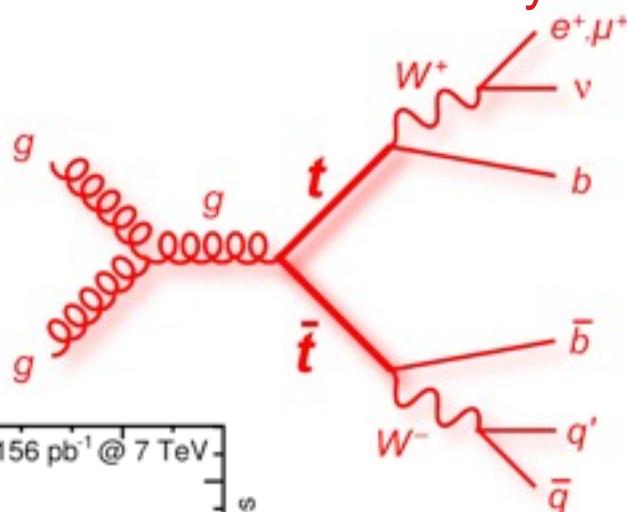
QCD multijets

- Model using data
- Normalize to data



Top quark pairs

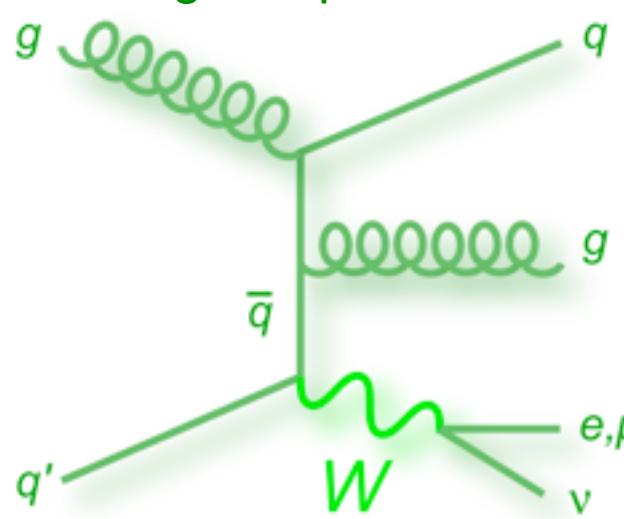
- Model using MC@NLO/Herwig
- Normalize to theory



W+jets

- Model using Alpgen/Herwig

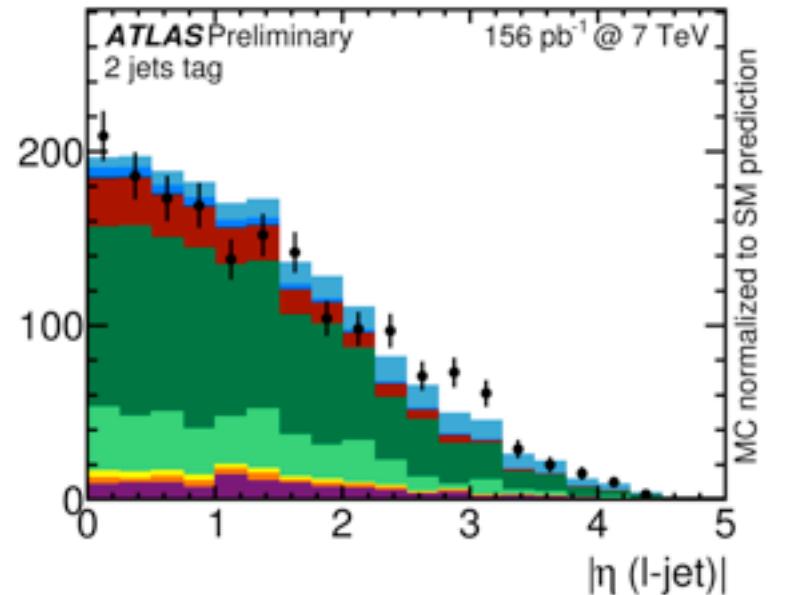
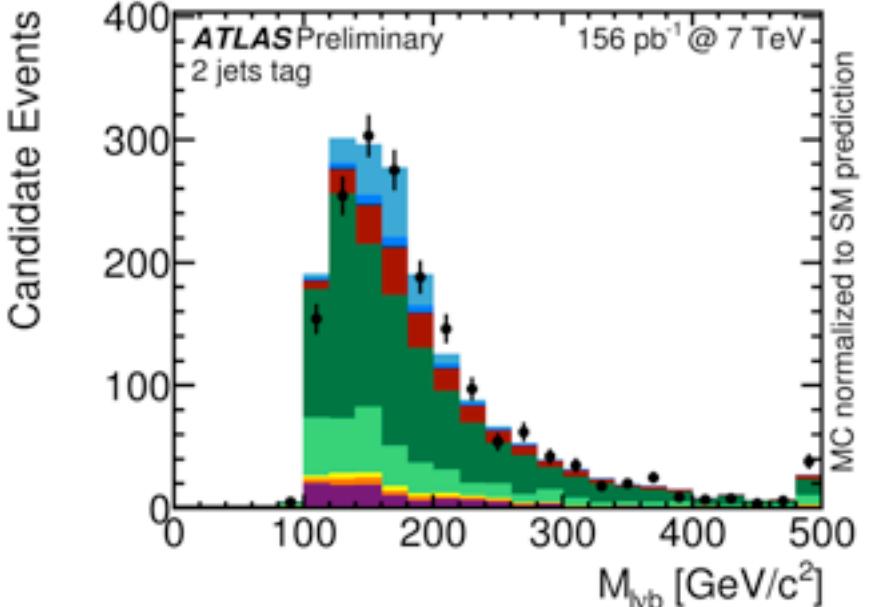
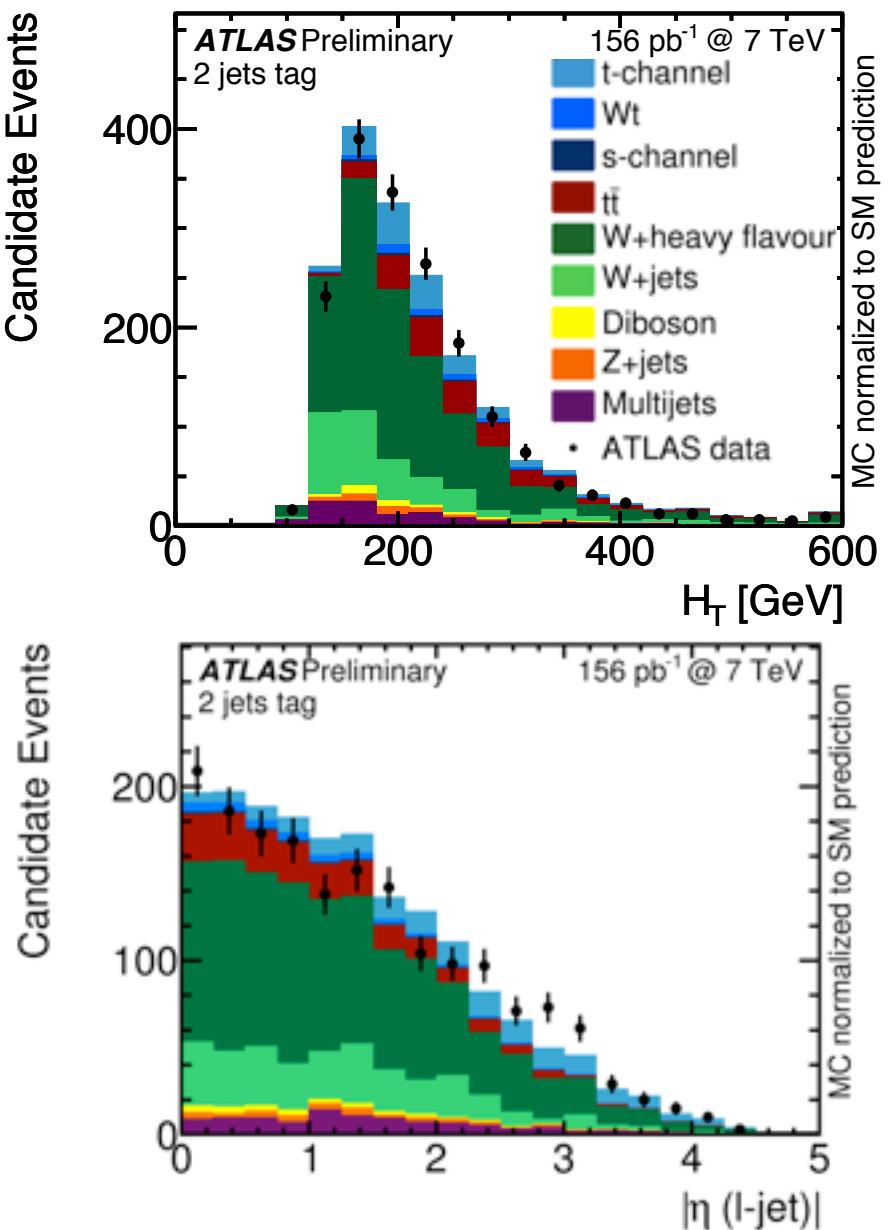
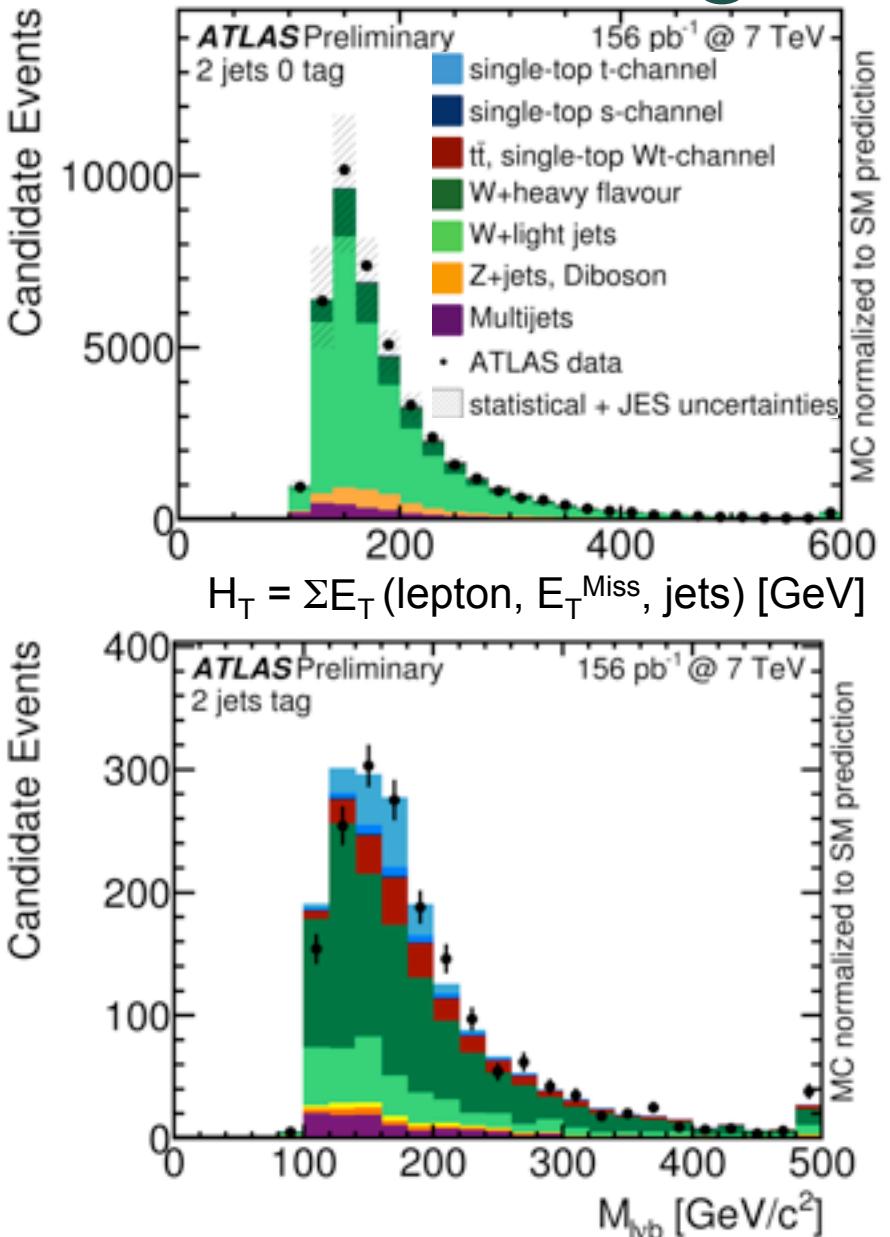
- Normalize to data
 - In pre-tag sample
 - In tag sample



Small contributions from Z+jets, dibosons

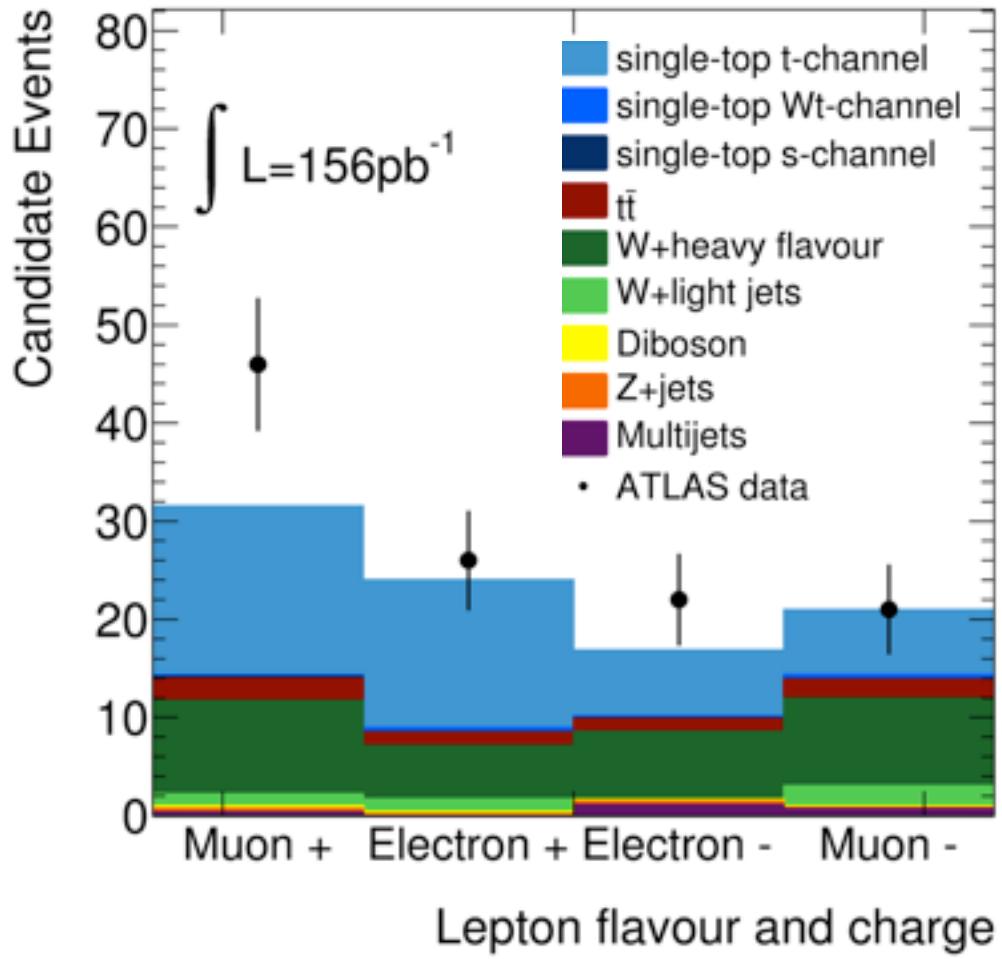
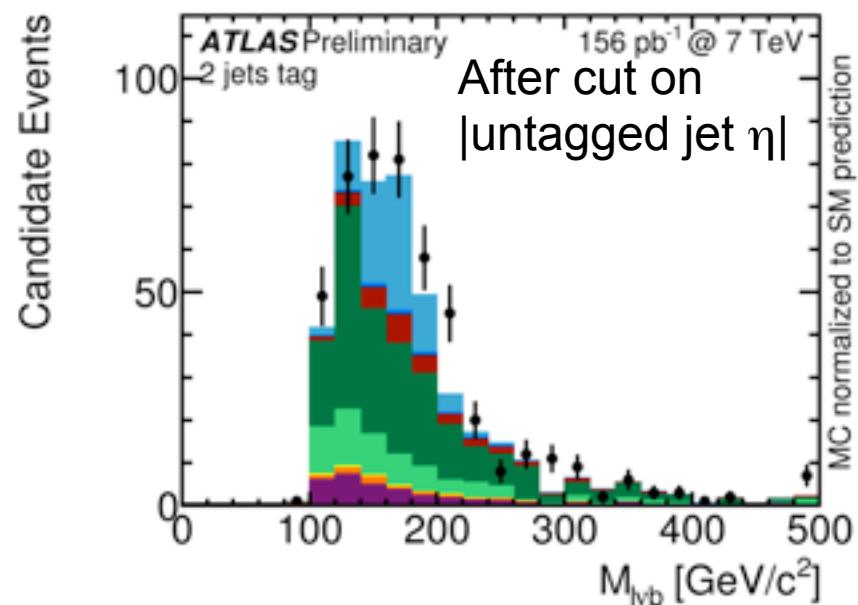
- Normalize MC to theory

Background Modeling

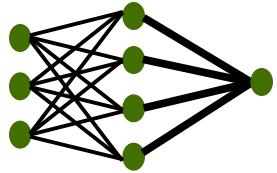


Cut-based t-channel analysis

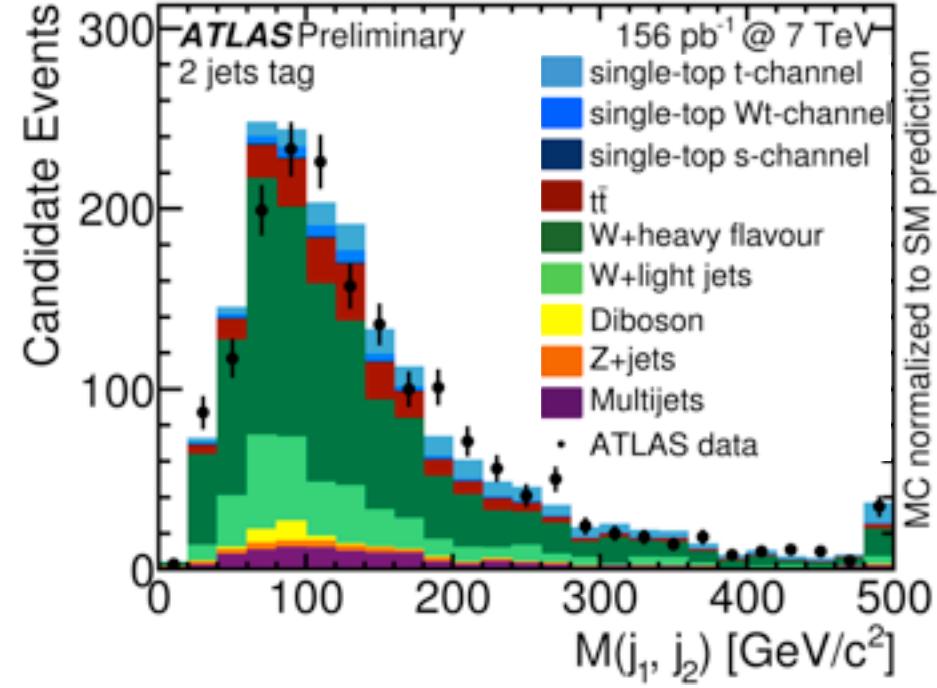
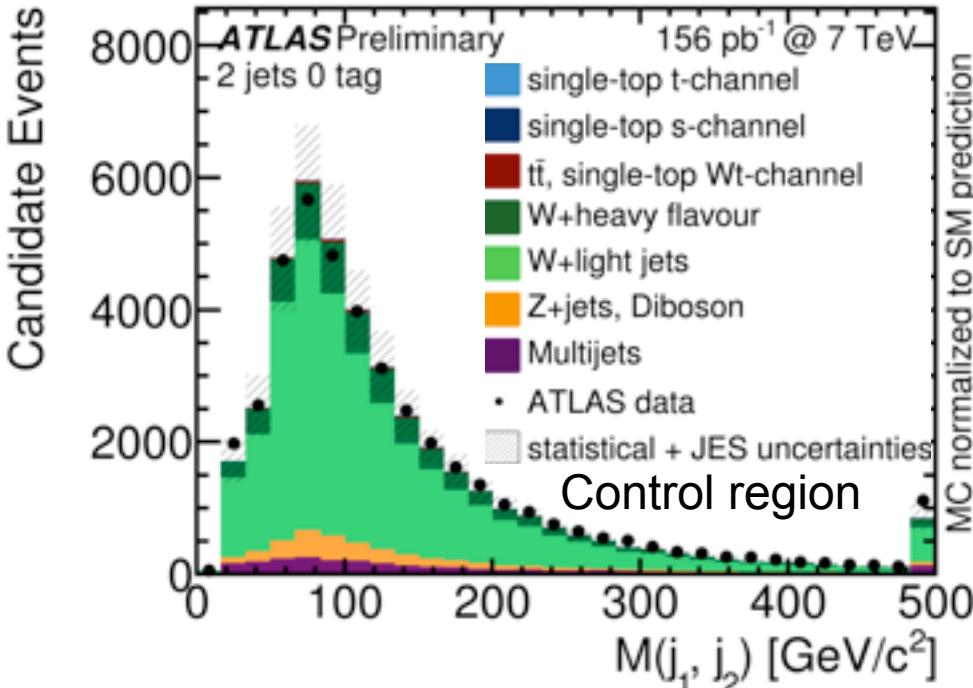
- $| \text{un-tagged jet } \eta | > 2.0$
- $140 \text{ GeV} < \text{top quark mass} < 190 \text{ GeV}$
- $|\Delta\eta(\text{lepton}, \text{b-tagged jet})| < 1.5$
- $|\text{b-tagged jet } \eta| < 2.0$
- $H_T > 180 \text{ GeV}$
- separate by lepton flavor and top charge



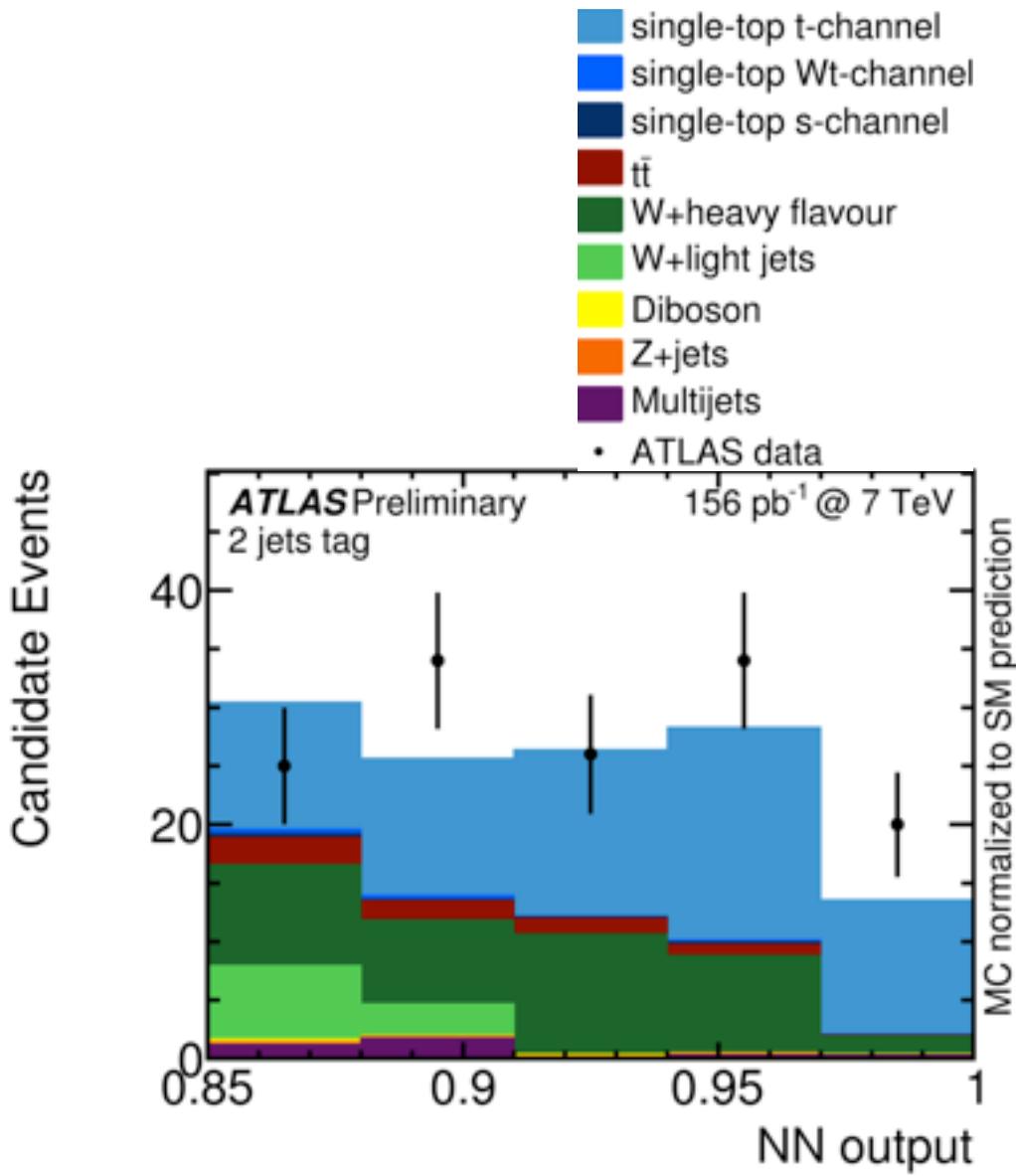
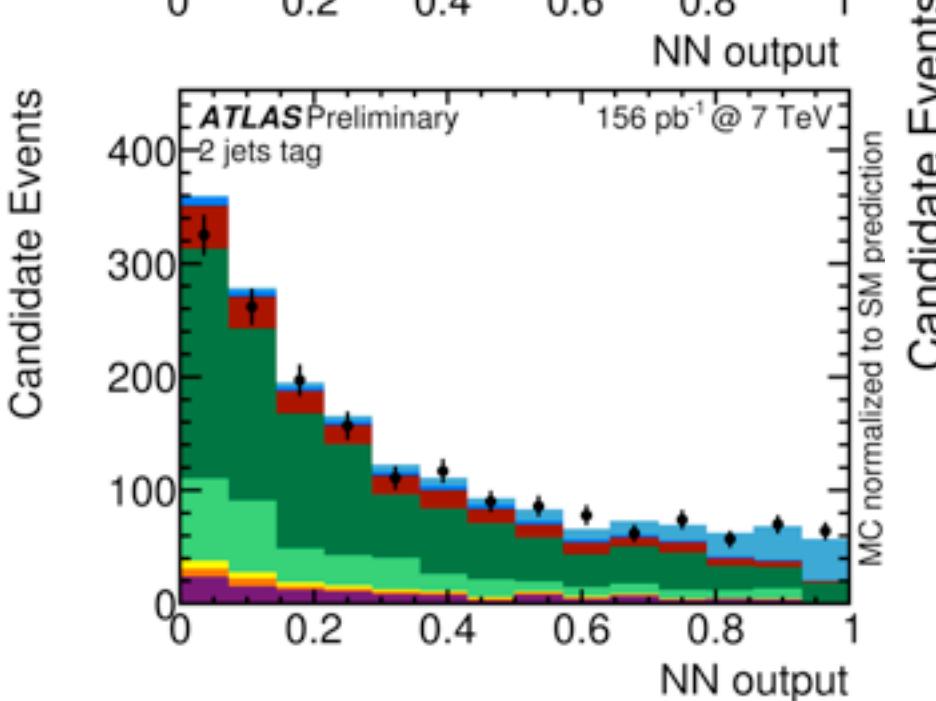
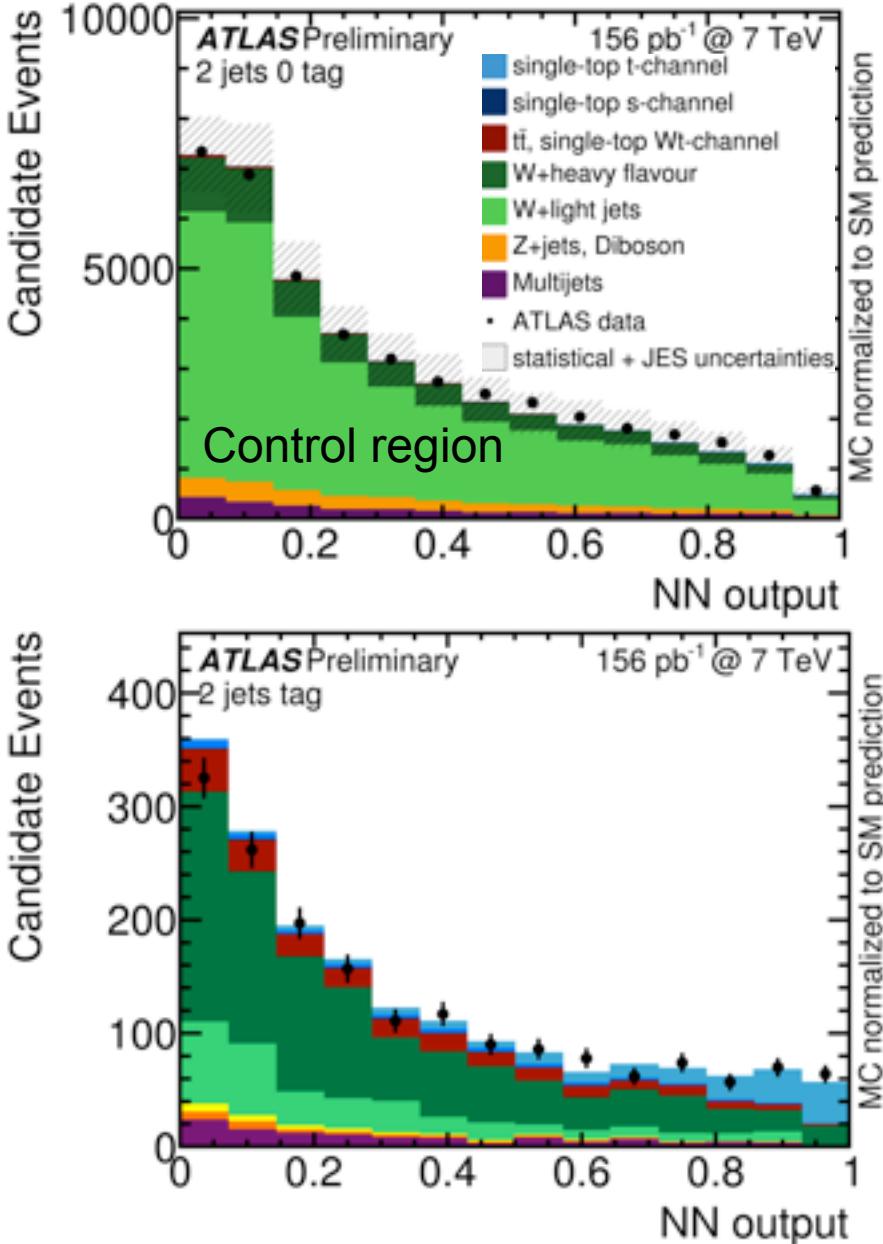
Neural network t-channel analysis



- 22 input variables
- 1 hidden layer, 1 output node
- Check each variable in tag and 0-tag control sample



Neural network output



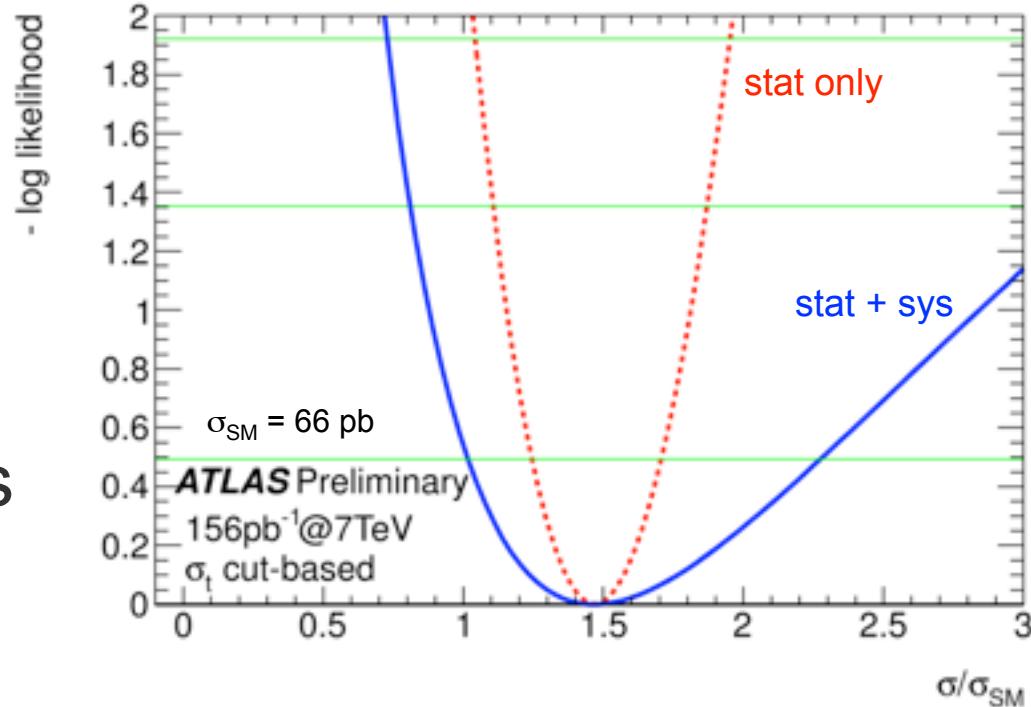
Single top selection

- Cut-based selection: separate by + and – lepton
- NN selection: cut at 0.86

	Cut-based		Neural network
	Lepton +	Lepton -	
t -channel	32.2 ± 11.7	13.3 ± 3.6	66.4 ± 19.6
s -channel	0.3 ± 0.1	0.2 ± 0.1	0.9 ± 0.2
Wt	0.6 ± 0.2	0.6 ± 0.3	1.0 ± 0.2
$t\bar{t}$	3.6 ± 1.8	3.2 ± 1.6	6.3 ± 3.0
W +jets	2.6 ± 1.4	2.1 ± 2.6	9.0 ± 1.9
W +heavy flavour	14.9 ± 5.3	15.9 ± 5.4	35.8 ± 12.7
Dibosons	0.3 ± 0.2	0.3 ± 0.1	0.4 ± 0.1
Z +jets	0.6 ± 0.5	0.5 ± 0.4	1.0 ± 0.8
Multijets	1.6 ± 1.2	0.7 ± 0.9	3.6 ± 2.8
TOTAL Exp	56.9 ± 13.0	36.8 ± 7.2	124.4 ± 23.7
S/B	1.31	0.57	1.14
DATA	72	43	134

Cut-based cross section result

- Statistical analysis using profile likelihood
 - In 4 bins of lepton type and charge
- Expected cross section systematic uncertainties
 - B-tagging $\sim 12\%$
 - MC statistics $\sim 11\%$
 - ISR/FSR $\sim 7\%$
 - Signal modeling $^{+48}_{-24}\%$
 - Total systematics $^{+61}_{-35}\%$
- Statistical uncertainty 22%



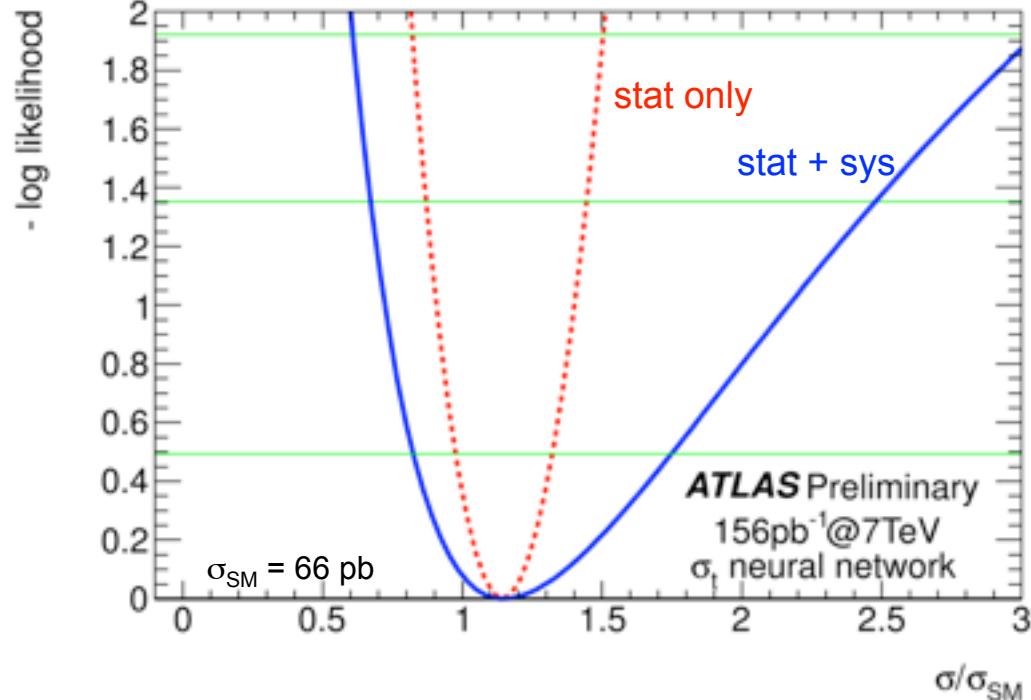
Observed cross section:

$$\sigma_t = 97^{+54}_{-30} \text{ pb}$$

Observed (expected) significance:
6.3 (4.5) σ

Neural network cross section result

- Statistical analysis of event count after cut
- Expected cross section systematic uncertainties
 - B-tagging $\sim 12\%$
 - MC statistics $\sim 11\%$
 - ISR/FSR $\sim 6\%$
 - Signal modeling $^{+36}_{-20}\%$
 - Total systematics $^{+55}_{-29}\%$
- Statistical uncertainty 17%



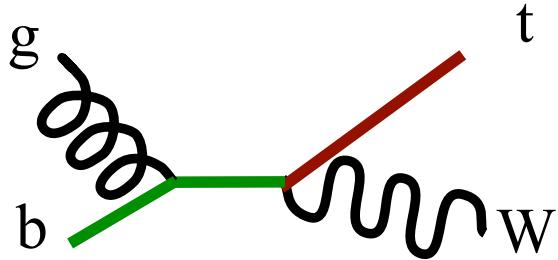
Observed cross section:

$$\sigma_t = 76 ^{+41}_{-21} \text{ pb}$$

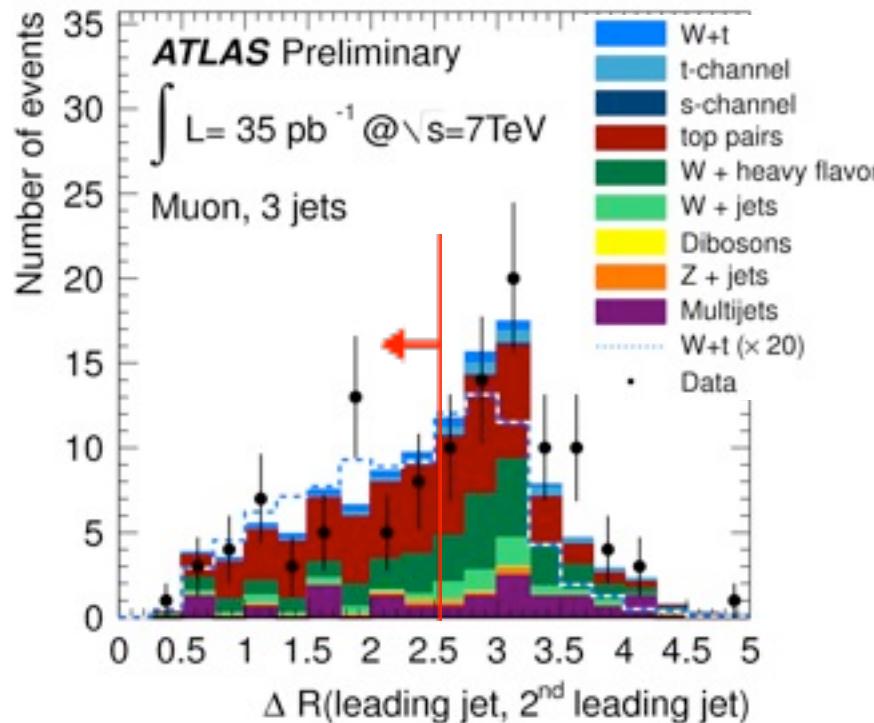
Observed (expected) significance:

$$6.2 (5.7) \sigma$$

Search for Wt associated production



- Never before seen!
- 1 jet + 2 final state W bosons
- Lepton+jets search in 35 pb^{-1} :
 - B-tag jet $p_T > 35 \text{ GeV}$
 - $\Delta R(j_1, j_2) < 2.5$
 - 2, 3, 4 jets



Muon	2 jets	3 jets	4 jets
Wt-channel	2.4 ± 0.5	2.8 ± 0.4	1.2 ± 0.2
Total expected	66.2 ± 14.6	50.5 ± 8.2	32.6 ± 4.4
Data	74	50	37
S/B	0.04	0.06	0.04

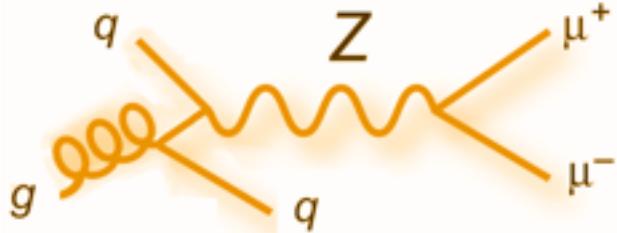
Wt di-lepton analysis

- Select 2 opposite charge leptons ($E_T > 20$ GeV)
- $E_T^{\text{Miss}} > 50$ GeV
- =1 jet ($E_T > 20$ GeV)
 - No b-tag requirement

Backgrounds:

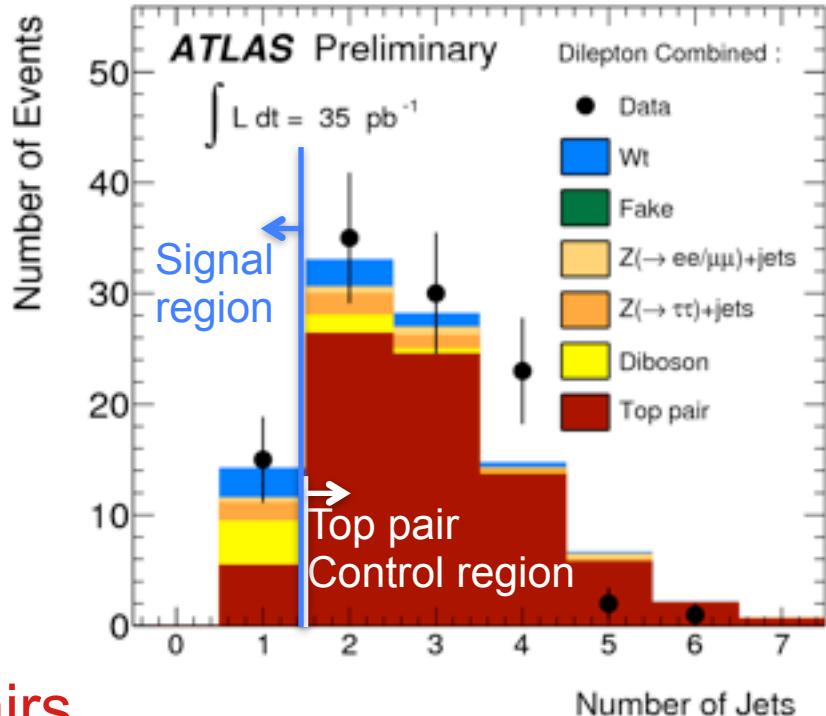
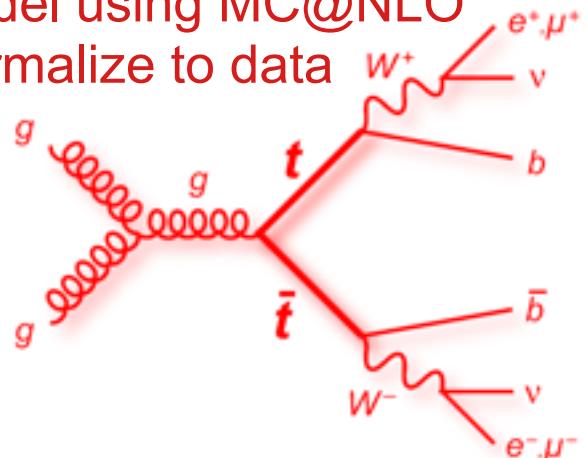
Drell-Yan

- Model using Alpgen
- Normalize to data



Top quark pairs

- Model using MC@NLO
- Normalize to data

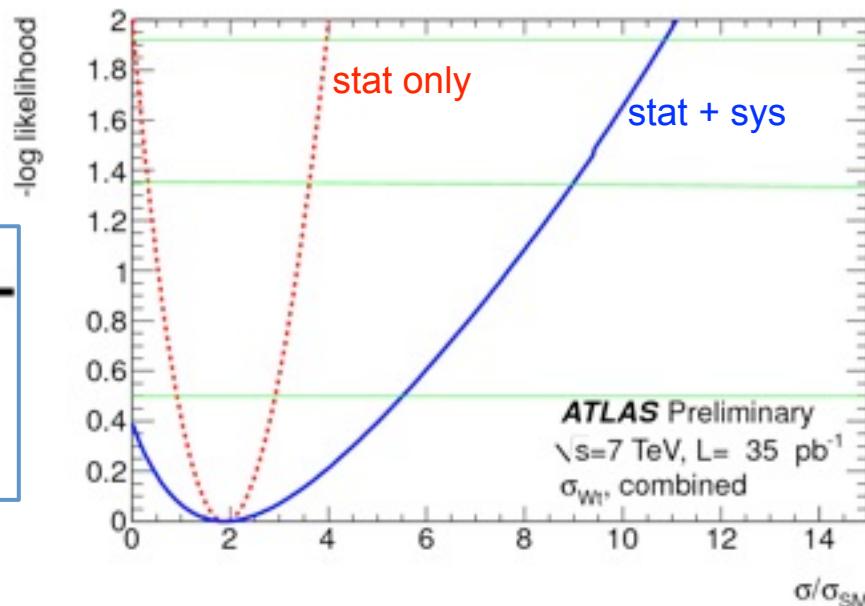


Smaller contributions from $Z \rightarrow \tau\tau$, dibosons, $W + \text{jets}$, multijets

Single top Wt result

- Combine 9 di-lepton and lepton+jets channels
- Include systematic uncertainty correlations
 - Dominant systematics are jet energy scale, b-tagging modeling, ISR/FSR, MC statistics
- Expected (observed) limit on σ_{Wt} corresponds to
 $6.3 (10.5) * \sigma_{Wt}^{SM}$

95% CL Upper Limit	Expected	Observed
Lepton+jets	123 pb	198 pb
Dilepton	112 pb	110 pb
Combined	94 pb	158 pb



Summary

- LHC observation of t-channel single top production
 - Using 156 pb^{-1} of 2011 ATLAS data
 - Lepton + 2 jets final state
 - NN-based signal selection
 - Observed cross section $\sigma_t = 76^{+41}_{-21} \text{ pb}$
 - Observed significance 6.2σ
 - Cross-checked with cut-based analysis
- First limit on Wt associated production
 - Using 35 pb^{-1} of 2010 data
 - 95% CL limit of 158 pb

Larger LHC datasets will bring separate observation of all single top processes and many new physics searches